

Pre-CO₂ Injection Reservoir Assessment, Naval Petroleum Reserve No. 3, Natrona County, Wyoming by Kristin Dennen, William Burns, Robert Burruss, Kendra Hatcher

OBJECTIVE

To provide geochemical analyses of oils and gases from wells in Naval Petroleum Reserve No. 3 (NPR-3), also known as the Teapot Dome oil field, as baselines which can be monitored to detect changes in reservoirs caused by CO₂ injection.

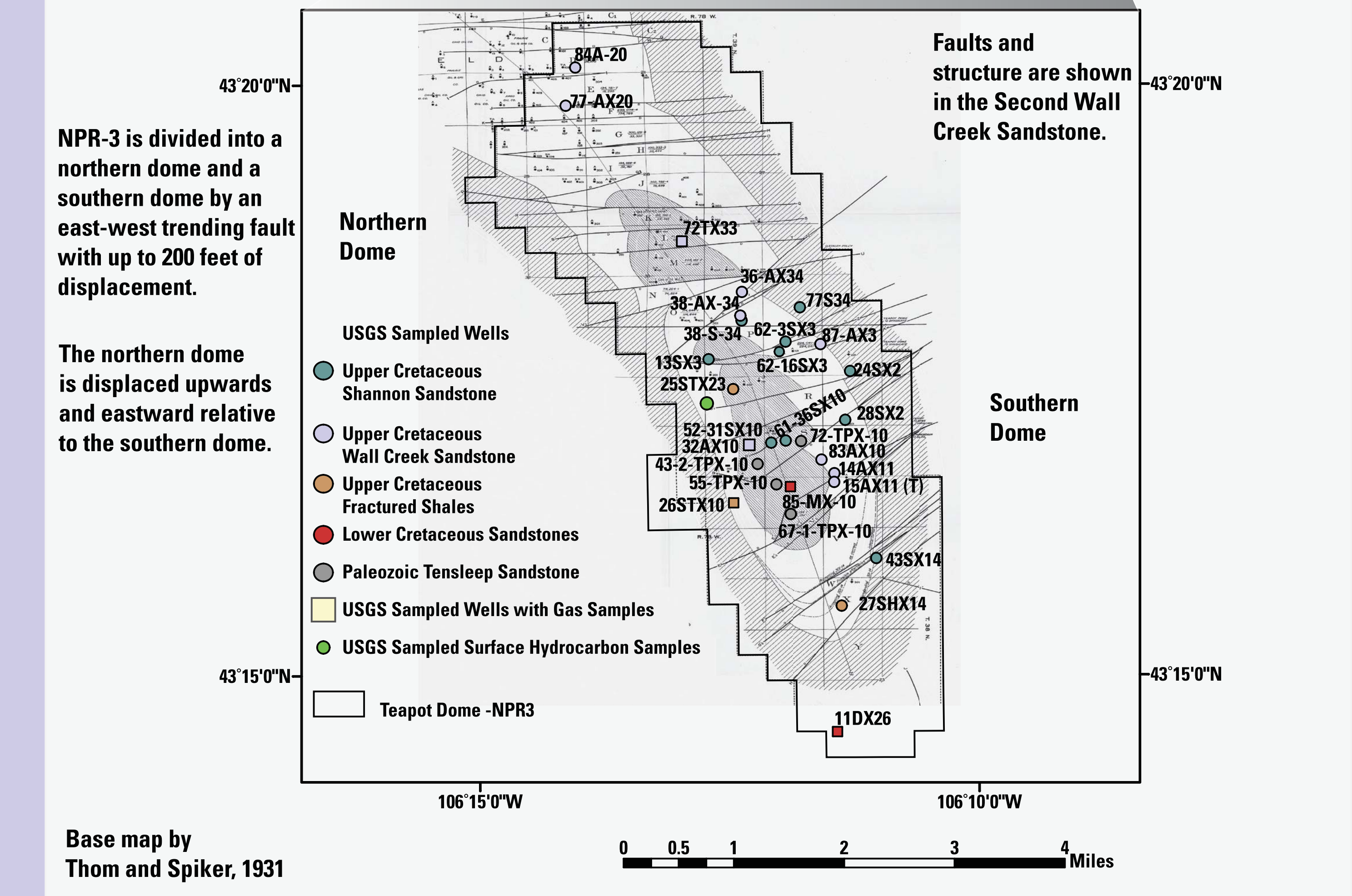
REASON

NPR-3 is a potential long term field-scale test site for development of CO₂ sequestration methods and reservoir processes may change when CO₂ is injected.

METHODS

Compositions of twenty-nine oil samples and six gas samples, provided by the U.S. DOE Rocky Mountain Oilfield Testing Center (RMOTC) from the Cretaceous Shannon, Steele, Niobrara, Second and Third Wall Creek, Muddy, Dakota, and Pennsylvanian Tensleep formations within NPR-3 are being compared with stratigraphic and structural trends observed in the oil field.

SAMPLE LOCATIONS , STRUCTURE AND STRATIGRAPHY



CHARACTERISTICS OF FIELD

Location
The NPR-3 and the adjacent giant Salt Creek field exist as faulted domes in the Salt Creek Anticline on the southwestern margin of the Powder River Basin, north of Casper in Natrona County, Wyoming. The fields are included in the Basin Margin Anticline Play of the Powder River Basin petroleum province (Dolton and Fox, 1996).

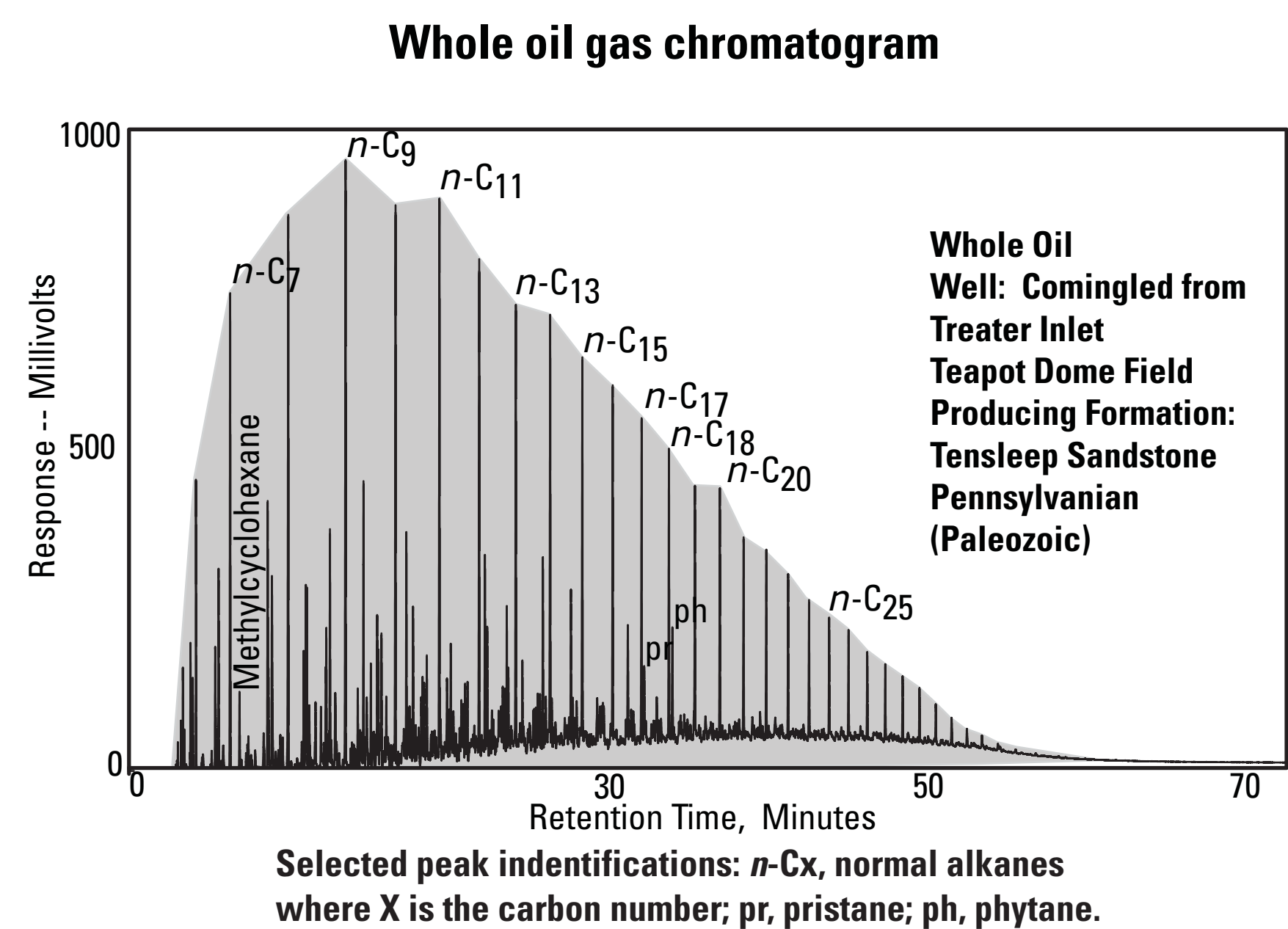
Structure and Oil Traps
The highly fractured Teapot Dome anticlinal structure acts as the main trap for hydrocarbons in the NPR-3. Wegemann (1911, 1918) mapped an east-west trending normal fault with up to 200 plus feet of displacement separating the NPR-3 into two domes. The northern dome is displaced eastward and upward relative to the southern dome. Anticlinal traps, fault closures and combinations of the two are typical in NPR-3 as well as in other fields of this type, including the adjacent Salt Creek field (Dolton and Fox, 1996).

Oil Source Rocks and Producing Horizons
The Pennsylvanian Phosphoria Formation supplied oil to the Pennsylvanian Tensleep sandstone oil reservoir and the major oil source rock for the Cretaceous sandstone reservoirs, the Dakota, the Muddy, the Frontier (the Wall Creek sands), and the Shannon, is the Upper Cretaceous Mowry Shale, with minor contributions from the Niobrara, the Frontier and the Steele shales (Momper & Williams, 1979).

PRELIMINARY RESULTS

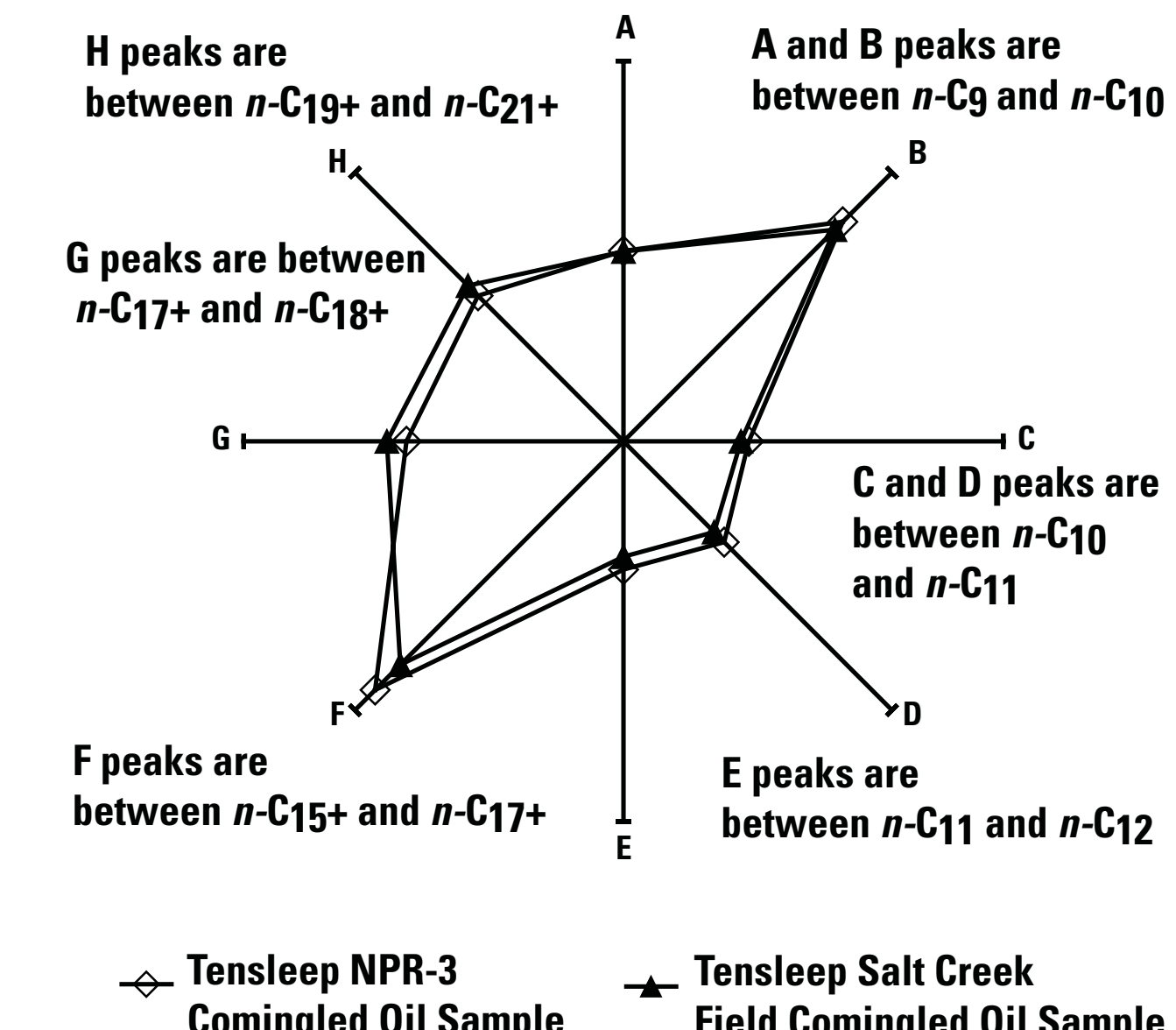
WHOLE OIL GAS CHROMATOGRAPHY

Whole oil gas chromatography is used as a method to "fingerprint" individual oil samples. A whole oil chromatogram appears as a complex collection of different sized peaks, all representing components of crude oil which are sensitive to many factors, among which are depositional environment and lithology of the oil source rock, age of the oil and processes within the oil reservoir. Peak areas and heights are roughly equivalent to concentration and their ratios can be used to describe characteristics of reservoirs and fields.



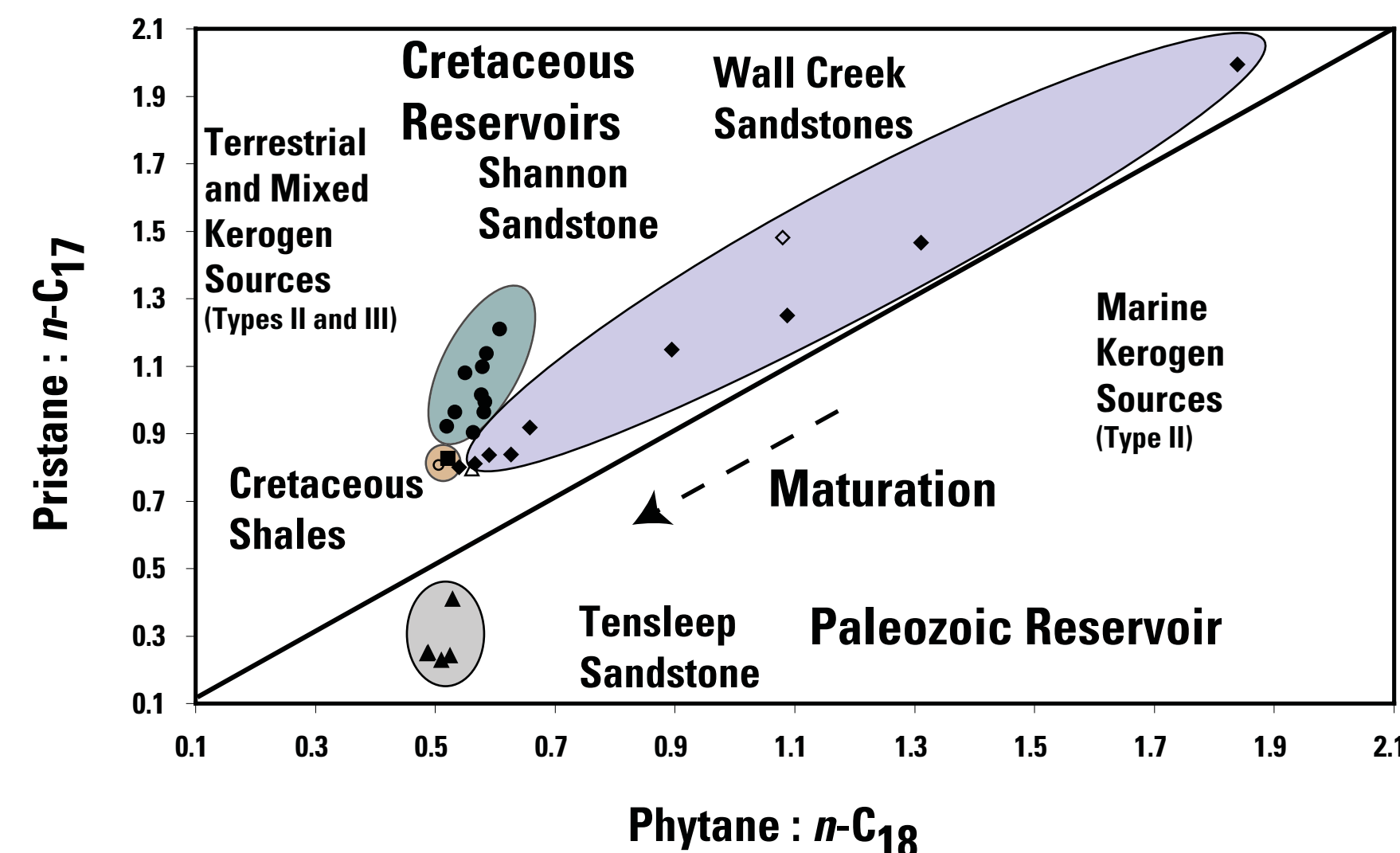
Diminished gas range (*n*-C₂ - *n*-C₆) *n*-alkanes indicate water washing associated with the very high water to oil ratio of fluids produced from Tensleep wells and the fact that the Tensleep oil is thought to have migrated from outside the basin. (Mauk and Burruss, 2002; Momper and Williams, 1979)

Reservoir Continuity ? Tensleep Sandstone Polar Plot



A polar plot (not shown) using data from oil chromatograms of Second Wall Creek oils showed more variation among the oil samples within NPR-3 than the analytical method. This implies that the reservoir- may be compartmentalized by faults.

Oil Types and Sources in NPR-3



Bacteria prefer to attack *n*-alkanes relative to the isoprenoids pristane and phytane, and *n*-C₁₇ relative to *n*-C₁₈. Pristane and phytane are derivatives of chlorophyll. The ratio of pristane to phytane can be indicative of the depositional environment of the organic source material (kerogen) for the hydrocarbons. (Hunt, 1996)

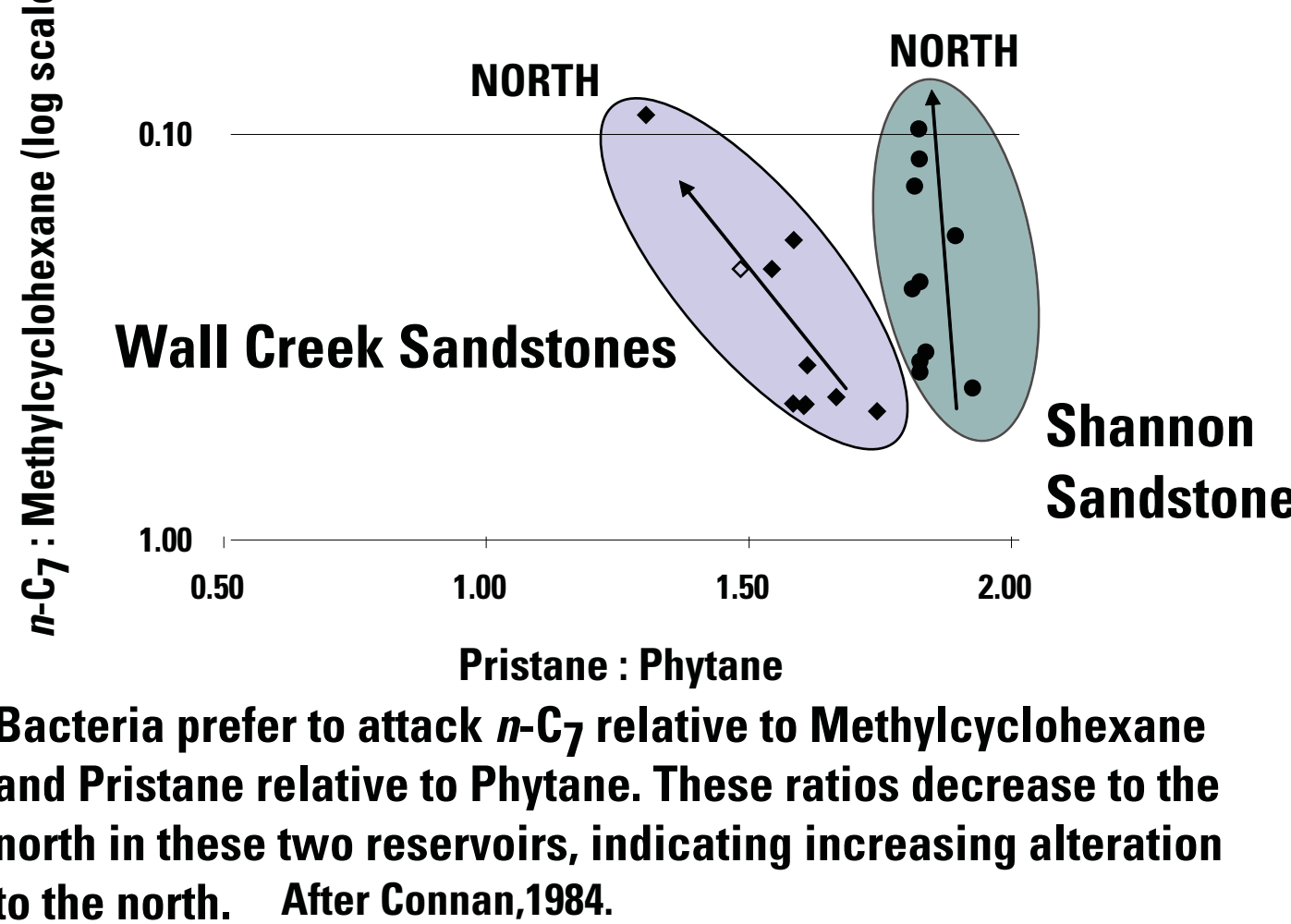
Comparing unique oil fingerprints from gas chromatography has been used to evaluate reservoir continuity. Peak area ratios from non-*n*-alkane peaks found in all of the oil samples under consideration are plotted on a polar plot with each axis representing a peak area ratio. Peaks in the region between *n*-C₈ and *n*-C₂₀ are used.

If the plots of individual oils are different shapes, the oils are considered to be from different pools or reservoirs. If they are the same, the oils are considered to be from a continuous reservoir or pool.

In this plot of Tensleep reservoir samples, from 2 different fields, the differences in the fingerprints are less than the difference in the analytical method.

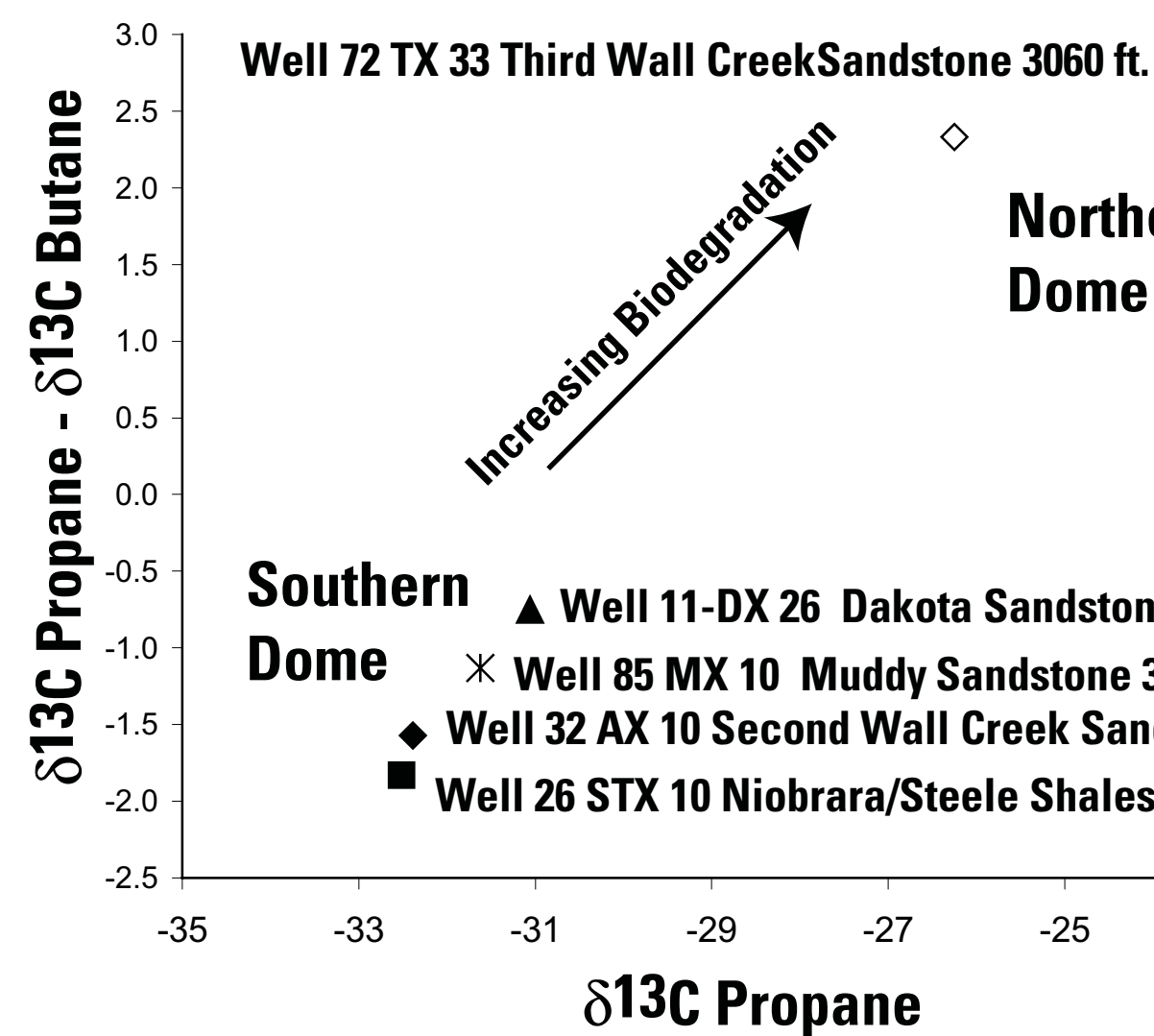
This implies that there is communication between the Tensleep reservoir in NPR-3 and the Tensleep reservoir in the Salt Creek field, and/or the Tensleep is not affected by structural compartmentalization. (Kaufman, Ahmed, and Elsinger, 1990.)

Aerobic Microbial Degradation of Oil Alteration Trends in Upper Cretaceous Sandstone Reservoirs, NPR-3



Biodegradation of C₂+ Gases

The ratios in this diagram emphasize the relative differences between isotope enrichment and concentration of propane and butane.



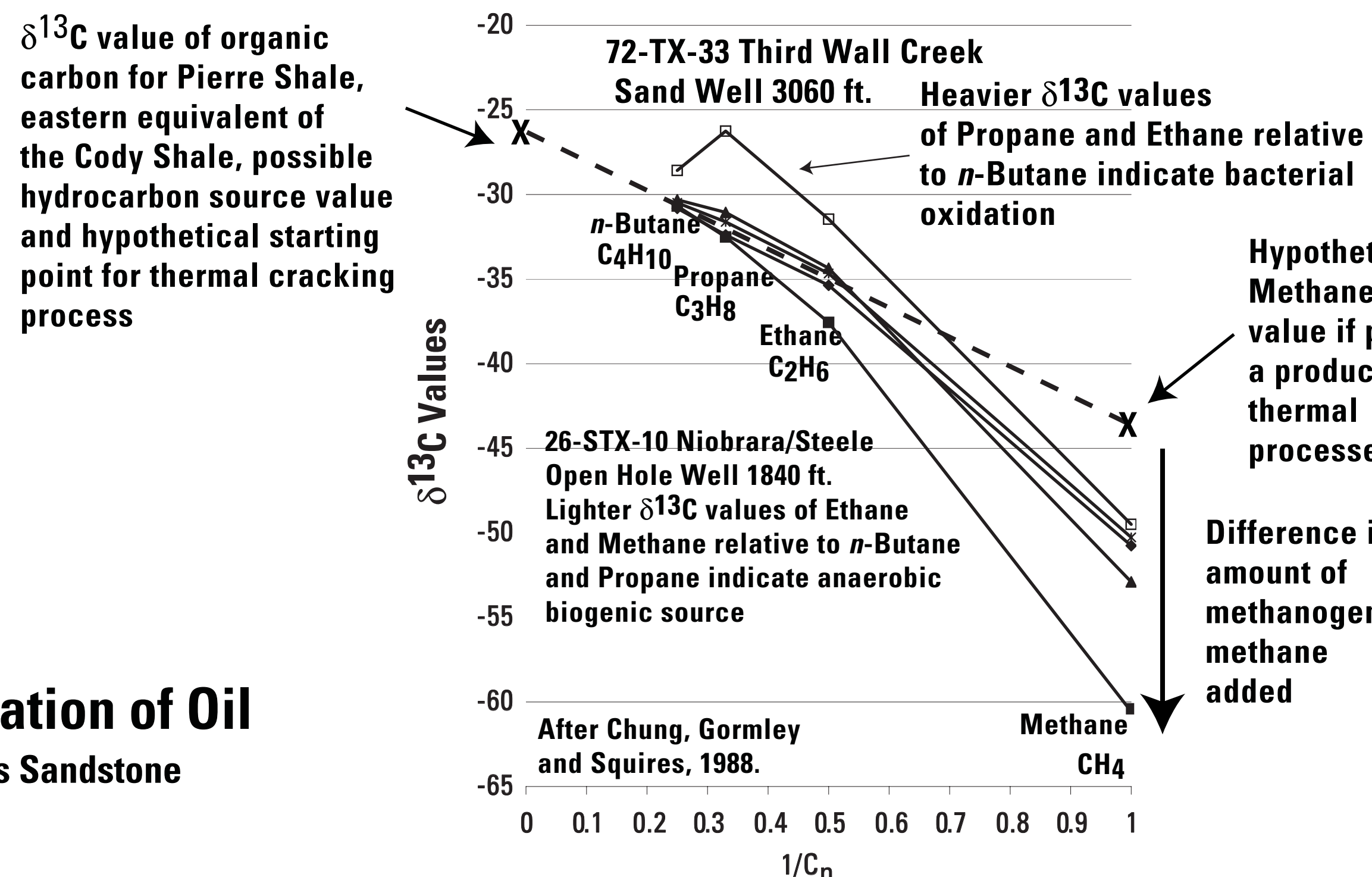
Bacteria prefer to attack propane rather than butane, reducing the concentration of propane relative to butane, and fractionating the stable isotope composition, enriching the remaining propane in $\delta^{13}\text{C}$. After Wenger, 2002.

GAS ISOTOPE AND COMPOSITIONAL ANALYSES

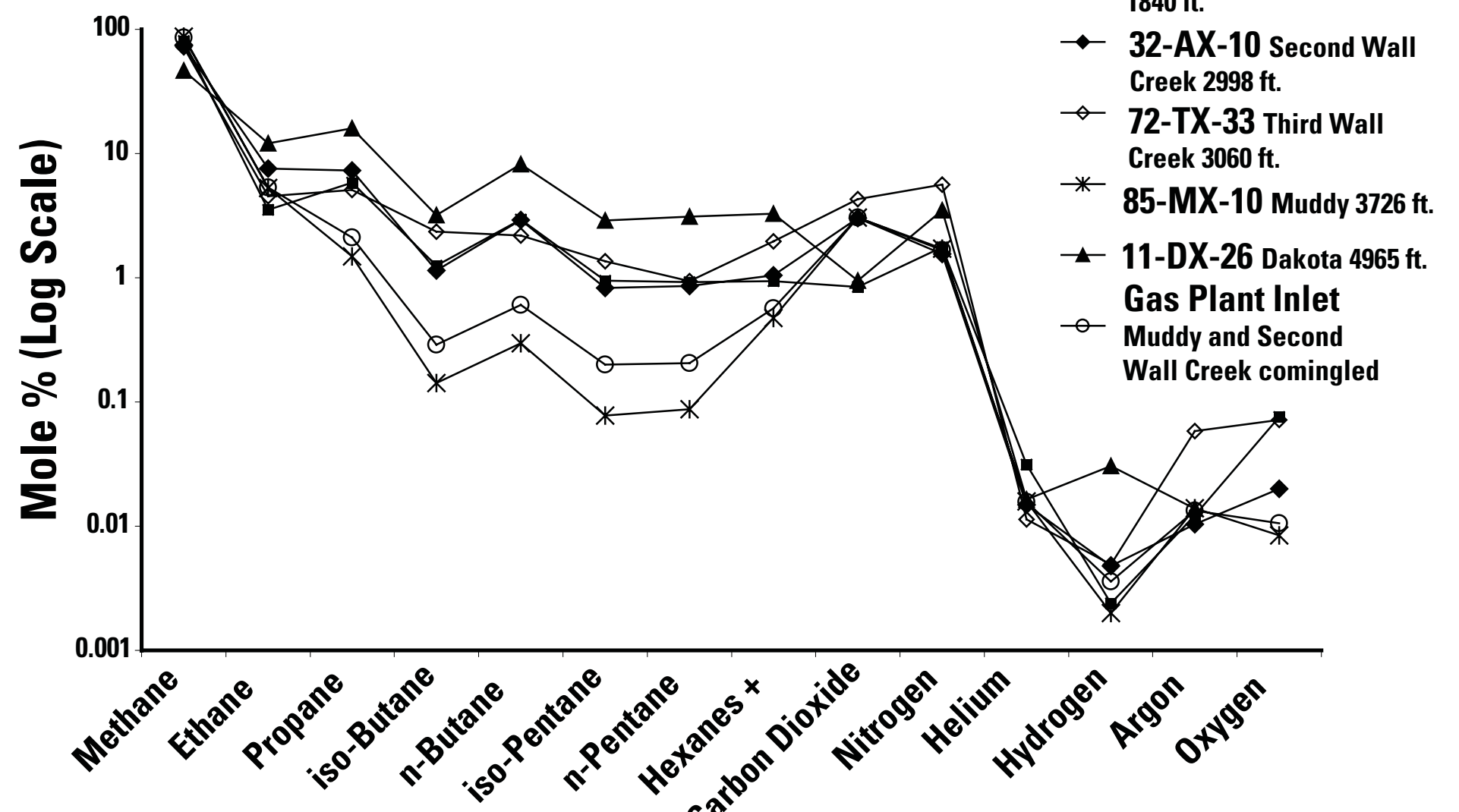
Relative abundances of hydrocarbon and non-hydrocarbon components in natural gases and variations in their isotopic compositions provide geochemical signatures which identify gas from a particular reservoir. These signatures can be used to identify gas sources, describe processes of gas formation, biodegradation, and to track migrating gas.

NPR-3 NATURAL GAS PLOT

Hypothetical line for $\delta^{13}\text{C}$ values of natural gas resulting from thermal cracking of higher hydrocarbons is straight. Deviations from this line indicate mixing of thermogenic and biogenic products. (Chung, Gormley and Squires, 1988)

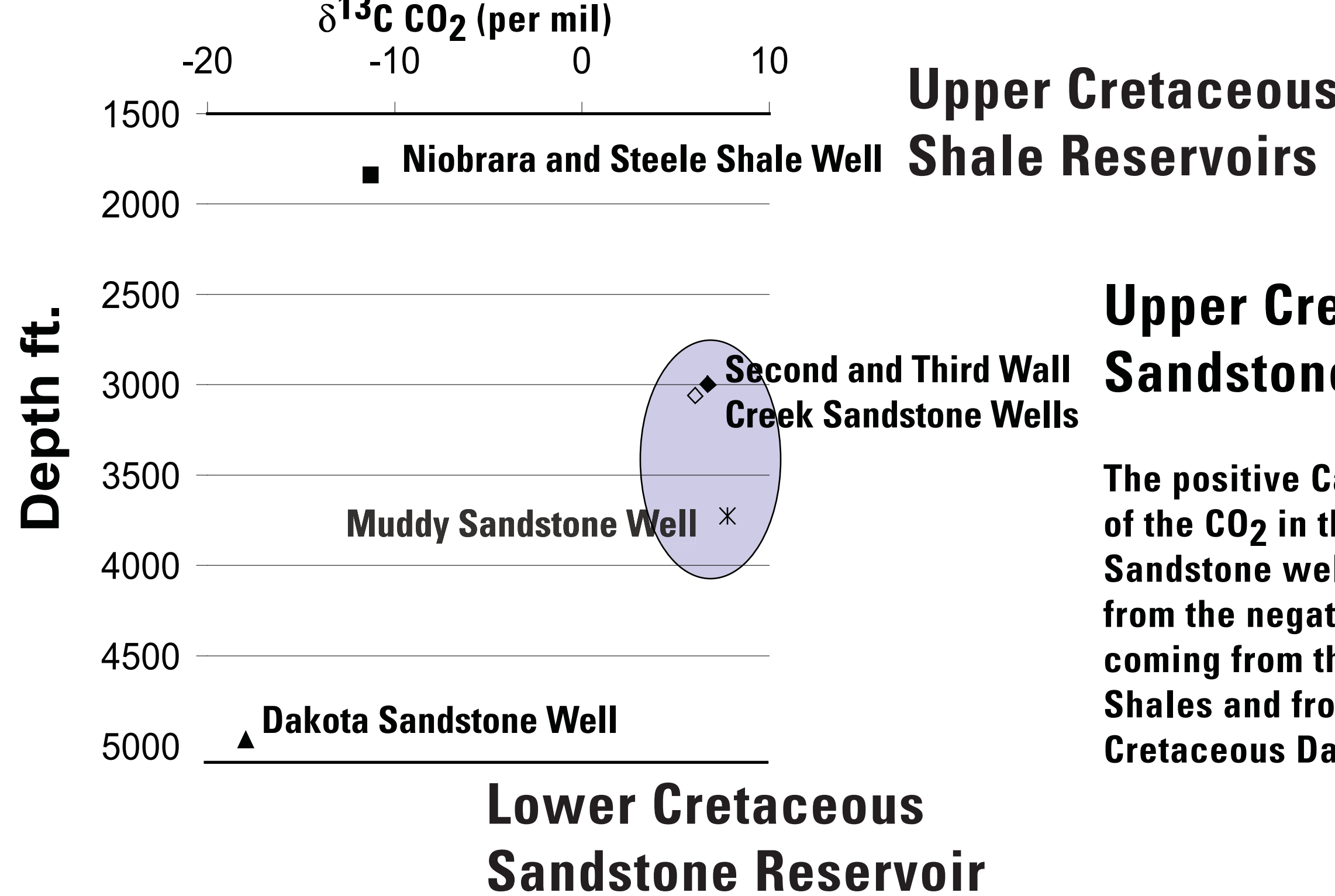


June 2004 Baseline Gas Sample Profiles



Different Sources of CO₂

Carbon Isotope Values of CO₂ in NPR-3 Wells by Depth



SUMMARY OF OBSERVATIONS

High resolution gas chromatography of oils is a cost-effective method which rapidly produces characteristic data for an individual oil sample. The data are easily stored, quickly available for comparison to other analyses and provide baseline data for geochemical assessments of reservoir characteristics.

Gas isotopic and compositional analyses provide information on the sources of the gas, whether or not there is mixing of gases from different sources and can be used to trace subsequent gas migration.

Alterations in Upper Cretaceous oil profiles in NPR-3 follow structural and stratigraphic trends. The least degraded samples occur to the south where reservoirs are deeper and the most degraded are to the north where stratigraphically equivalent reservoirs are shallower.

The Tensleep reservoir in the NPR-3 appears to be in communication with the Tensleep reservoir in the Salt Creek field. The reservoir in the Second Wall Creek sandstone may be compartmentalized by faulting.

Gas isotope analyses indicate two different sources of microbial alteration of oils. The alteration in the gases follows the trend observed in the oils.

ONGOING WORK AND FUTURE PROJECTS

Work in progress includes the study of biomarker data from oil analyses which will enable better definition of the biodegradation processes in the reservoirs. Biomarker data analyses will also help clarify the relationship of the surface hydrocarbons to the reservoir fluids.

Quantitative analysis of the light hydrocarbons in oils will define evaporative fractionation characteristics in reservoirs which can be monitored for phase changes during CO₂ injection.

Monitoring of Cretaceous reservoirs using oil and gas compositional analyses and comparing that to baseline data will help detect the possible appearance of a migrating Tensleep signature during CO₂ injection, indicating leakage.

The isotopic composition of the gas from wells in NPR-3 needs to be studied in greater detail to better define the sources of the gas and to provide a baseline for soil gas monitoring.

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